

§ 1065.642 SSV, CFV, and PDP molar flow rate calculations.

This section describes the equations for calculating molar flow rates from various flow meters. After you calibrate a flow meter according to § 1065.640, use the calculations described

in this section to calculate flow during an emission test.

(a) *PDP molar flow rate.* Based upon the speed at which you operate the PDP for a test interval, select the corresponding slope, a_1 , and intercept, a_0 , as calculated in § 1065.640, to calculate molar flow rate, \dot{n} as follows:

$$\dot{n} = f_{\text{nPDP}} \cdot \frac{p_{\text{in}} \cdot V_{\text{rev}}}{R \cdot T_{\text{in}}}$$

Eq. 1065.642-1

Where:

$$V_{\text{rev}} = \frac{a_1}{f_{\text{nPDP}}} \cdot \sqrt{\frac{p_{\text{out}} - p_{\text{in}}}{p_{\text{out}}}} + a_0$$

Eq. 1065.642-2

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Example:

$$a_1 = 0.8405 \text{ (m}^3/\text{s)}$$

$$f_{\text{nPDP}} = 12.58 \text{ r/s}$$

$$p_{\text{out}} = 99.950 \text{ kPa}$$

$$p_{\text{in}} = 98.575 \text{ kPa} = 98575 \text{ Pa} = 98575 \text{ kg}/(\text{m} \cdot \text{s}^2)$$

$$a_0 = 0.056 \text{ (m}^3/\text{r)}$$

$$R = 8.314472 \text{ J}/(\text{mol} \cdot \text{K}) = 8.314472 \text{ (m}^2 \cdot \text{kg})/(\text{s}^2 \cdot \text{mol} \cdot \text{K})$$

$$T_{\text{in}} = 323.5 \text{ K}$$

$$V_{\text{rev}} = \frac{0.8405}{12.58} \cdot \sqrt{\frac{99.950 - 98.575}{99.950}} + 0.056$$

$$V_{\text{rev}} = 0.06383 \text{ m}^3/\text{r}$$

$$\dot{n} = 12.58 \cdot \frac{98575 \cdot 0.06383}{8.314472 \cdot 323.5}$$

$$\dot{n} = 29.428 \text{ mol/s}$$

(b) SSV molar flow rate. Based on the C_d versus $Re^\#$ equation you determined according

to § 1065.640, calculate SSV molar flow rate, \dot{n} during an emission test as follows:

$$\dot{n} = C_d \cdot C_f \cdot \frac{A_t \cdot p_{\text{in}}}{\sqrt{Z \cdot M_{\text{mix}} \cdot R \cdot T_{\text{in}}}}$$

Eq. 1065.642-3

Example:

$$A_t = 0.01824 \text{ m}^2$$

$$p_{\text{in}} = 99.132 \text{ kPa} = 99132 \text{ Pa} = 99132 \text{ kg}/(\text{m} \cdot \text{s}^2)$$

$$Z = 1$$

$$M_{\text{mix}} = 28.7805 \text{ g/mol} = 0.0287805 \text{ kg/mol}$$

$$R = 8.314472 \text{ J}/(\text{mol} \cdot \text{K}) = 8.314472 \text{ (m}^2 \cdot \text{kg})/(\text{s}^2 \cdot \text{mol} \cdot \text{K})$$

$$T_{\text{in}} = 298.15 \text{ K}$$

$$Re^\# = 7.232 \cdot 10^5$$

$$\gamma = 1.399$$

$$\beta = 0.8$$

$$\Delta p = 2.312 \text{ kPa}$$

$$\text{Using Eq. 1065.640-7,}$$

$$r_{\text{ssv}} = 0.997$$

$$\text{Using Eq. 1065.640-6,}$$

$$C_f = 0.274$$

Using Eq. 1065.640-5,

$$C_d = 0.990$$

$$\dot{n} = 0.990 \cdot 0.274 \cdot \frac{0.01824 \cdot 99132}{\sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 298.15}}$$

$$\dot{n} = 58.173 \text{ mol/s}$$

(c) *CFV molar flow rate.* Some CFV flow meters consist of a single venturi and some consist of multiple venturis, where different combinations of venturis are used to meter different flow rates. If you use multiple venturis and you calibrated each venturi independently to determine a separate discharge coefficient, C_d (or calibration coefficient, K_v), for each venturi, calculate the individual molar flow rates through each venturi and sum all their flow rates to determine \dot{n} . If you use multiple venturis and you calibrated each combination of venturis, calculate \dot{n} using the sum of the active

venturi throat areas as A_t , the square root of the sum of the squares of the active venturi throat diameters as d_t , and the ratio of the venturi throat to inlet diameters as the ratio of the square root of the sum of the active venturi throat diameters (d_t) to the diameter of the common entrance to all the venturis (D).

(1) To calculate the molar flow rate through one venturi or one combination of venturis, use its respective mean C_d and other constants you determined according to §1065.640 and calculate its molar flow rate \dot{n} during an emission test, as follows:

$$\dot{n} = C_d \cdot C_f \cdot \frac{A_t \cdot p_{in}}{\sqrt{Z \cdot M_{mix} \cdot R \cdot T_{in}}}$$

Eq. 1065.642-4

Example:

$$C_d = 0.985$$

$$C_f = 0.7219$$

$$A_t = 0.00456 \text{ m}^2$$

$$p_{in} = 98.836 \text{ kPa} = 98836 \text{ Pa} = 98836 \text{ kg}/(\text{m} \cdot \text{s}^2)$$

$$Z = 1$$

$$M_{mix} = 28.7805 \text{ g/mol} = 0.0287805 \text{ kg/mol}$$

$$R = 8.314472 \text{ J}/(\text{mol} \cdot \text{K}) = 8.314472 (\text{m}^2 \cdot \text{kg})/(\text{s}^2 \cdot \text{mol} \cdot \text{K})$$

$$T_{in} = 378.15 \text{ K}$$

$$\dot{n} = 0.985 \cdot 0.7219 \cdot \frac{0.00456 \cdot 98836}{\sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 378.15}}$$

$$\dot{n} = 33.690 \text{ mol/s}$$

(2) To calculate the molar flow rate through one venturi or a combination of venturis, you may use its respective mean, K_v , and other constants you determined according to §1065.640 and calculate its molar flow rate during an

emission test. Note that if you follow the permissible ranges of dilution air dewpoint versus calibration air dewpoint in Table 3 of §1065.640, you may set $M_{mix-cal}$ and M_{mix} equal to 1. Calculate \dot{n} as follows:

$$\dot{n} = \frac{K_v \cdot p_{\text{in}}}{\sqrt{T_{\text{in}}}} \cdot \frac{p_{\text{std}}}{T_{\text{std}} \cdot R} \cdot \frac{\sqrt{M_{\text{mix-cal}}}}{\sqrt{M_{\text{mix}}}}$$

Eq. 1065.642-5

Where:

$$K_v = \frac{V_{\text{stdref}} \cdot \sqrt{T_{\text{in-cal}}}}{p_{\text{in-cal}}}$$

Eq. 1065.642-6

V_{stdref} = volume flow rate of the standard at reference conditions of 293.15 K and 101.325 kPa.

$T_{\text{in-cal}}$ = venturi inlet temperature during calibration.

$p_{\text{in-cal}}$ = venturi inlet pressure during calibration.

$M_{\text{mix-cal}}$ = molar mass of gas mixture used during calibration.

M_{mix} = molar mass of gas mixture during the emission test calculated using Equation 1065.640–9.

Example:

$V_{\text{stdref}} = 0.4895 \text{ m}^3$

$T_{\text{in-cal}} = 302.52 \text{ K}$

$p_{\text{in-cal}} = 99.654 \text{ kPa} = 99654 \text{ Pa} = 99654 \text{ kg}/(\text{m} \cdot \text{s}^2)$

$p_{\text{in}} = 98.836 \text{ kPa} = 98836 \text{ Pa} = 98836 \text{ kg}/(\text{m} \cdot \text{s}^2)$

$p_{\text{std}} = 101.325 \text{ kPa} = 101325 \text{ Pa} = 101325 \text{ kg}/(\text{m} \cdot \text{s}^2)$

$M_{\text{mix-cal}} = 28.9656 \text{ g/mol} = 0.0289656 \text{ kg/mol}$

$M_{\text{mix}} = 28.7805 \text{ g/mol} = 0.0287805 \text{ kg/mol}$

$T_{\text{in}} = 353.15 \text{ K}$

$T_{\text{std}} = 293.15 \text{ K}$

$R = 8.314472 \text{ J}/(\text{mol} \cdot \text{K}) = 8.314472 (\text{m}^2 \cdot \text{kg})/(\text{s}^2 \cdot \text{mol} \cdot \text{K})$

$$R = 8.314472 \text{ J}/(\text{mol} \cdot \text{K}) = 8.314472 (\text{m}^2 \cdot \text{kg})/(\text{s}^2 \cdot \text{mol} \cdot \text{K})$$

$$K_v = \frac{0.4895 \cdot \sqrt{302.52}}{99654} = 0.000074954 \text{ m}^4 \cdot \text{s} \cdot \text{K}^{0.5} / \text{kg}$$

$$\dot{n} = \frac{0.000074954 \cdot 98936}{\sqrt{353.15}} \cdot \frac{101325}{293.15 \cdot 8.314472} \cdot \frac{\sqrt{0.0289656}}{\sqrt{0.0287805}}$$

$$\dot{n} = 16.457 \text{ mol/s}$$

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§ 1065.644 Vacuum-decay leak rate.

This section describes how to calculate the leak rate of a vacuum-decay

leak verification, which is described in § 1065.345(e). Use the following equation to calculate the leak rate \dot{n}_{leak} , and compare it to the criterion specified in § 1065.345(e):